Interconnection Feasibility Study Report
GIP-IR735-FEAS-R1

Generator Interconnection Request 735

150 MW Wind Generating Facility

New Prospect II, NS

2024-06-03

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted a Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS) Interconnection Request (IR#735) for a proposed 150 MW wind generation facility interconnected to the NSPI Transmission System, with a Commercial Operation Date of 2027-12-31. The Point of Interconnection (POI) requested by the customer is the 138 kV line L-6555 (existing line is named L-6613), approximately 9.6 km from the 74N-Springhill substation.

There are twenty-two (22) transmission Interconnection Requests in the Advanced Stage Transmission and Distribution Queue that must be included in the study models for IR#735.

This study assumes that the addition of generation from IR#735 will displace coal-fired generation in eastern Nova Scotia for both NRIS and ERIS.

Interconnection on L-6555 will require a three-breaker 138 kV ring bus since L-6613 is currently classified as a Bulk Power System (BPS) element. This new substation is expected to be classified as BPS under NPCC criteria and Bulk Electric System (BES) under NERC criteria. As IR#735 has dispersed generation totaling more than 75 MVA, each generator will be classified as a NERC BES element. The IR#735 Interconnection Customer substation is also classified as part of the BES, subject to the applicable NERC Reliability Criteria.

No thermal loading violations were identified due to the addition of IR#735. No violations of voltage criteria were found due to the addition IR#735.

Data provided by the IC indicates that IR#735 will be utilizing the Nordex Delta4000 - N163/6.X 7.0 MW wind turbines. In addition, a +/- 36 MVAr STATCOM is included in IR#735, connected to the low voltage (34.5 kV) side of the IC substation transformer. Based on supplied interconnection data and assumptions, IR#735 meets the net power factor requirement of +/- 0.95 at the high voltage side of Interconnection Facility. The adequacy of reactive power supply will be further investigated in the System Impact Study as specific details of the collector circuits become available. It is noted that the proposed Nordex Delta4000 - N163/6.X 7.0 MW wind turbine models (with reactive power support from the STATCOM) will also meet the requirement to produce full rated reactive power down to zero MW output (with the wind turbine operating in STATCOM mode).

NS Power notes that NERC standard PRC-029-1 is currently in development. As proposed, this standard will impose performance requirements for voltage and frequency ride through behaviour on inverter-based generating resources. It is anticipated that this standard will be applicable to the project currently under study. The Interconnection Customer is advised to consider the requirements of PRC-029-1 in their project design to ensure that their project can conform to these requirements. Conformance will be validated at the System Impact Study stage.

IR#735 was not found to adversely impact the short-circuit capabilities of existing circuit breakers. The minimum short circuit level at the Interconnection Facility 34.5 kV bus is 407 MVA with all lines in service and IR#735 off-line, resulting in a Short Circuit Ratio (SCR) of 2.7. This falls to 282 MVA with L-6555 open at 74N-Springhill, resulting in a SCR of 1.9. These conditions should

be discussed with the wind turbine manufacturer to determine if the equipment can operate, or if modifications are required. Also, proximity to IR#669 reduces the effective SCR in the area. NSPI system short circuit level may decline over time with changes to transmission configuration and generation mix, as noted in TSIR section 7.4.15. IR#735 must be able to accommodate these changes.

The largest calculated voltage flicker P_{st}=P_{lt} of 0.185 for continuous operation does not exceed NSPI's required limit with L-6555 open at the 74N-Springhill end. The project design must meet NSPI requirements for low-voltage ride-through and voltage control. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

The preliminary value for the unit loss factor is calculated as +4.3% at the POI, net of any losses on the IC facilities up to the POI.

To connect IR#735 as NRIS or ERIS, the preliminary non-binding cost estimate for interconnecting 150 MW to the L-6555 POI is $44,812,500 including a 25% contingency. This cost estimate includes:

- A three-breaker ring bus substation at the POI.
- A 30 km spur line from the POI to the Interconnection Customer's Interconnection Facility (ICIF).
- Modifications to arming values of existing Limited Impact RAS (NS Import Monitor and NS Export Monitor), subject to NPCC approval.

In this estimate, $7,400,000 (plus 25% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP. The remainder of the costs are fully funded by the Interconnection Customer.

The preliminary cost estimate does not include any supplemental equipment that is potentially required to meet the NSPI power factor and/or inertia requirements. It also does not include costs to address any potential stability issues identified at the SIS stage based on dynamic analysis, costs related to findings of the electromagnetic transient (EMT) analysis, and it assumes that RAS modifications are approved by NPCC.

The estimated time to construct the Transmission Providers Interconnection Facilities and any Network Upgrades is 24-36 months after receipt of funds and cleared right of way from the customer. These estimates will be further refined in the System Impact Study and the Facility Study.

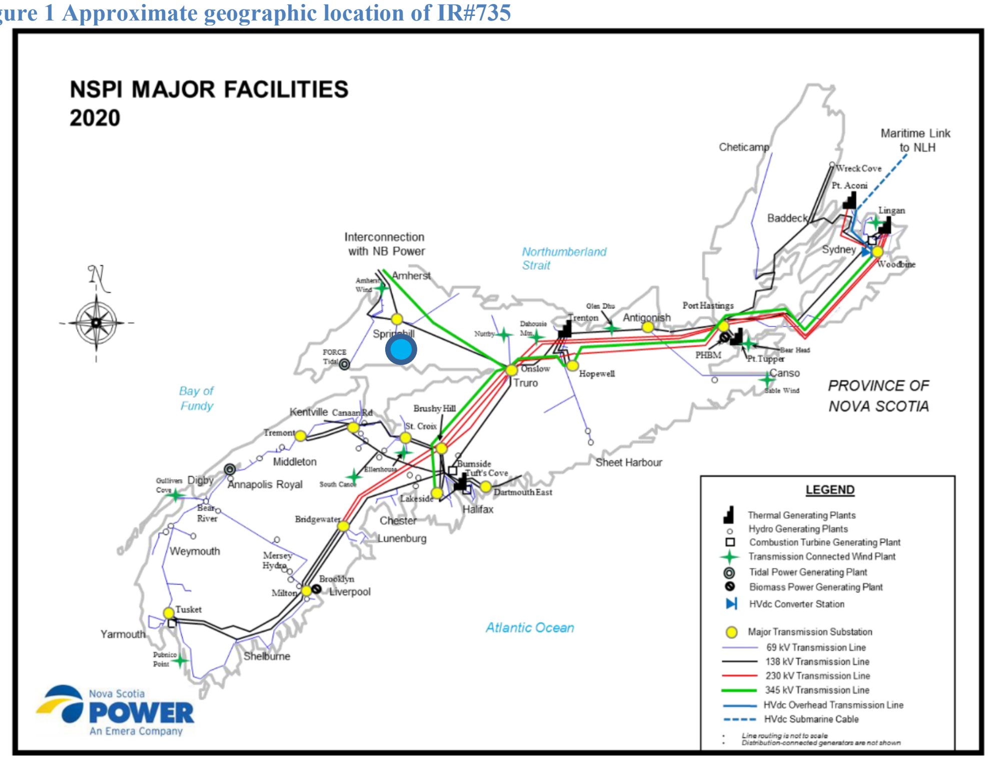
Table of Contents

1 Introduction

This Feasibility Study report (FEAS) presents the results of a Feasibility Study Agreement for the connection of "New Prospect II" with an installed capacity of 154 MW, capped at output of 150 MW. This wind generation facility interconnected to NSPI system as Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

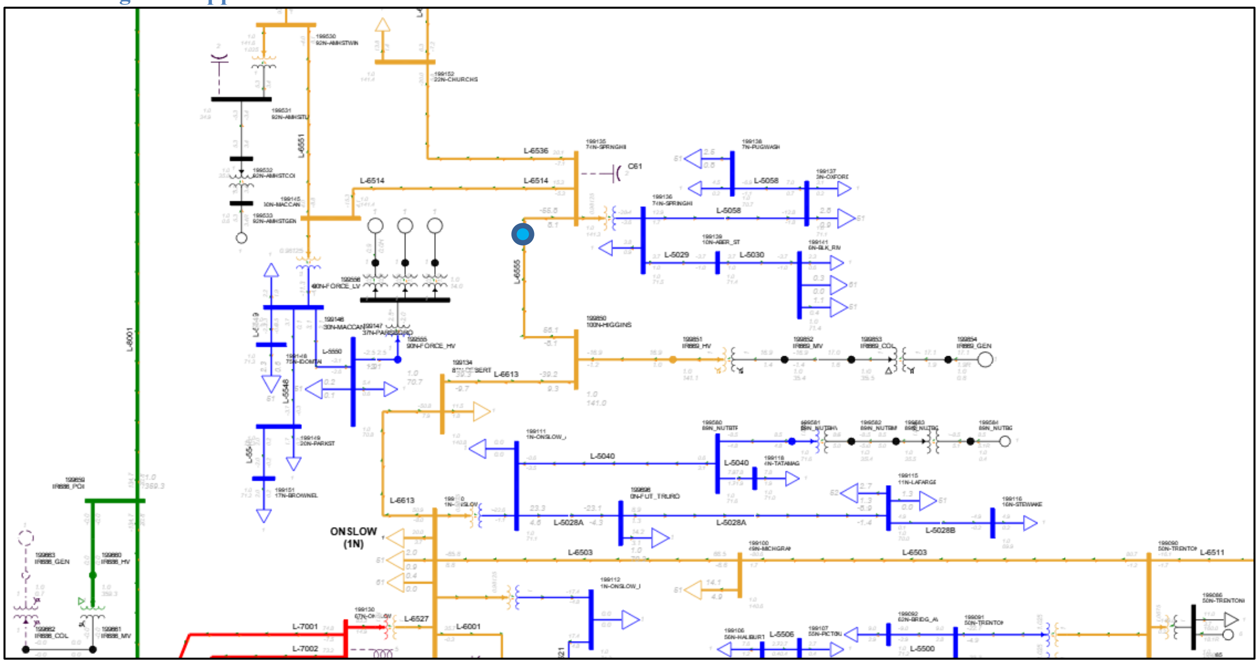
This project is listed as Interconnection Request #735 in the NSPI Interconnection Request Queue and will be referred to as IR#735 throughout this report. Interconnection Customer (IC) identified L-6555[1] as the Point of Interconnection (POI), 9.6 km from 74N-Springhill substation. This wind generation facility will be connected to the POI via a 30 km long 138 kV transmission line from the Point of Change of Ownership (PCO). Figure 1 shows the approximate geographic location of the proposed POI (blue circle) and Figure 2 shows the approximate electrical location (blue circle).

Figure 1 Approximate geographic location of IR#735



[1] The Designation of Point of Interconnection in the Interconnection Feasibility Study Agreement was L-6613. However, after connecting IR#669, the line where IR#735 is connected to is renamed to L-6555.

Figure 2 Approximate electrical location of IR#735



2 Scope

The objective of this FEAS is to provide a preliminary evaluation of system impacts from interconnecting the proposed generation facility to the NSPI transmission system at the requested location. The assessment will identify potential impacts on transmission element loading, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the proposed generation increases the short-circuit duty of any existing circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria are applied.

The scope of the FEAS includes the modeling of the power system in normal state (with all transmission elements in service) under anticipated load and generation dispatch conditions. A power flow and short circuit analysis is performed to provide the following information:

- Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection, and any network upgrades necessary to address the short circuit issue associated with IR#735. Expected minimum short circuit capability will also be identified for the purpose of Short Circuit Ratio analysis.

- Preliminary identification of any thermal overload or voltage violations resulting from the interconnection and identification of the necessary network upgrades to allow full output of the proposed facility. Thermal limits are applied to the seasonal (summer/winter) emergency ratings of the transmission elements. Voltage violations occur when the post-contingency transmission bus voltage is outside the range of +/- 10% of the nominal voltage.

- Preliminary analysis of the ability of the proposed Interconnection Facility to meet the reactive power, power quality and cold-weather capability requirements of the NSPI Transmission System Interconnection Requirements[2] (TSIR).

- Preliminary description and high-level non-binding estimated cost and time to construct the facilities required to interconnect the generating facility to the transmission system.

- For comparative purposes, the impact of IR#735 on incremental losses under standardized operating conditions is examined.

This FEAS is based on a power flow and short circuit analysis and does not include a complete determination of facility changes/additions required to increase the system transfer capabilities that may be required to meet the design and operating criteria established by NSPI, the Northeast Power Coordinating Council (NPCC), and the North American Electric Reliability Corporation (NERC). These requirements will be determined by a more detailed analysis in the subsequent interconnection System Impact Study (SIS). An Interconnection Facilities Study (FAC) follows the SIS to ascertain the final cost estimate to the interconnect the generating facility.

3 Assumptions

This FEAS is based on the technical information provided by the IC. The POI and configuration are studied as follows.

1. NRIS and ERIS per section 3.2 of the Generation Interconnection Procedure (GIP).

2. Commercial operation date: 2027-12-31.

3. The Interconnection Customer Facility (ICIF) consists of 22 Nordex Delta4000 (N163/6.X) wind turbine generators (WTG), each rated 7.0 MW (154 MW total) connected to five collector circuits operating at voltage of 34.5 kV.

4. The line L-6613 is categorized Bulk Power System and the POI on L-6555 is expected to also be categorized Bulk Power System. It will therefore comply with applicable NPCC requirements.

[2] transmission-system-interconnection-requirements (nspower.ca)

5. The ICIF will require the construction of a 30 km, 138 kV transmission spur line from the POI to the IC 138/34.5 kV transformers. The IC will be responsible for providing the applicable Right-of-Way.

6. The generation technology used must meet NSPI requirements for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC substation step up transformer. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the wind farm transformer, or if the high voltage terminals are used, equipped with droop compensation controls. It is assumed that the generating units are not de-rated in their MW capability when delivering the required reactive power to the system. The IC has indicated that Nordex Delta4000 (N163/6.X) has a nominal power factor range from 0.907 capacitive to 0.90 inductive on the LV terminals of the GSU transformer.

7. Preliminary data was provided by the IC for the IC substation interconnection facility. The transformer was rated at 99/132/165 MVA and modeled with a positive-sequence impedance of 8.5% on 99 MVA with an X/R ratio of 38. The IC indicated this interconnection facility transformer has a wye-delta winding configuration with +/- 10% on-load tap changer. The impedance of each generator step-up transformer was modeled as 9% on 7.8 MVA with an assumed X/R ratio of 14.

8. Detailed collector circuit data was not provided, so typical data (R+jX = 0.01+j0.04 pu on system base 100 MVA) was assumed with the understanding that the net real and reactive power output of the plant will be impacted by losses through transformers and collector circuits.

9. A STATCOM, with +/- 36 MVAr reactive power limits, is connected at the low voltage side (34.5 kV) of the IC substation transformer.

10. Generation Interconnection Queue and OATT Transmission Service Queue that have completed a System Impact Study, or that have a System Impact Study in progress will proceed, as listed in Section 4 below.

11. It is required that the wind turbines are equipped with a “cold weather option” suitable for delivering full power under expected Nova Scotia winter environmental conditions according to section 7.6.9 of the TSIR.

12. Planning criteria meeting NERC Standard TPL-001-5.1 “Transmission System Planning Performance Requirements” and NPCC Directory 1 “Design and Operation of the Bulk Power System” as approved for use in Nova Scotia by the Utility And Review Board, are used in evaluation of the impact of any facility on the Bulk Electric System.

13. The rating of transmission facilities in the vicinity of IR#735 are shown in Table 1 and Table 2.

Table 1: Local Transmission Element Ratings

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-6555	1113 Beaumont	100°C	Switchgear	287/315 MVA	287/315 MVA
L-6514	556.5 Dove	60°C	Conductor/ Switchgear	140/154 MVA	143/157.3 MVA
L-6536	556.5 Dove	100°C	Conductor	213/234.3 MVA	242/266.2 MVA
L-6613	1113 Beaumont	100°C	Switchgear	287/315 MVA	287/315 MVA
L-6503A	1113 Beaumont	100°C	Switchgear	287/315 MVA	287/315 MVA
L-6503B	1113 Beaumont	85°C	Conductor/ Switchgear	287/315 MVA	287/315 MVA
L-6001A	556.5 Dove	60°C	Conductor	140/154 MVA	184/202.4 MVA
L-6001B	556.5 Dove	60°C	Conductor	140/154 MVA	184/202.4 MVA

Table 2: Local Transformer Ratings

Transformer	Summer/Winter Normal/Emergency
67N-T71	224/292 MVA

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS, except for Lingan Unit 2, which is assumed to be retired.

As of 2024/02/15, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are committed to the study base cases:

- IR426: GIA Executed
- IR516: GIA Executed
- IR540: GIA Executed
- IR542: GIA Executed
- IR517: GIA in Progress
- IR574: GIA Executed
- IR598: GIA Executed
- IR597: GIA Executed
- IR647: GIA in Progress
- IR664: FAC Complete
- IR662: FAC Complete
- IR670: FAC Complete
- IR671: FAC in Progress

- IR669: FAC Complete
- IR668: FAC Complete
- IR618: FAC Complete
- IR673: FAC Complete
- IR675: FAC Complete
- IR677: SIS in Progress
- IR697: SIS in Progress
- IR739: SIS in Progress
- IR742: SIS in Progress

The power system base cases for the feasibility study include all transmission connected IRs in the GIP queue up to and including IR742 with the exception of IR686, as the IR686 SIS was not completed when IR735 was initiated.

The inclusion of IR686 is not expected to negatively impact the operation of IR735 as it is understood to be paired with a dedicated load and associated network upgrades.

In addition, TSR-411 is included in the queue, which reflects the study of long-term firm Transmission Service Reservation (TSR) from New Brunswick to Nova Scotia. If approved by the NSUARB, the TSR is expected to be in service in 2028 and a system study is currently underway to determine the required updates to the Nova Scotia transmission system. This has not been included in the feasibility study and the following notice is posted to the OASIS site[3]:

> *Due to ongoing development discussions and engineering studies, the Transmission System Network Upgrades identified as part of Transmission Service Request #411 will not be included in the System Impact Study (SIS) Analysis for Generator Interconnection Procedures (GIP) Study Groups #32 to #35. GIP Study Group #32 to #35 analysis will be limited to the 2024 Transmission System configuration plus any material Network Upgrades identified in higher queued projects.*

5 Short-Circuit Duty / Short Circuit Ratio

The maximum (design) expected short-circuit level is 5,000 MVA (21 kA) on 138 kV systems and 10,000 MVA (25 kA) on 230 kV systems. The fault current characteristics for Nordex Delta4000 (N163/6.X) wind turbine is given as 3.36 times rated current, or X'd = 0.298 per unit on machine base MVA.

The short circuit analysis is performed using PSS®E version 34.7 for a classical fault study, 3LG and flat voltage profile at 1.0 pu. The maximum short circuit MVA values calculated

[3] Generation Interconnection Procedures| Nova Scotia Power (nspower.ca)

for scenarios with and without IR#735 at the POI and one-substation away are compared in Table 3.

Table 3: Short-Circuit Levels. IR#735 (Type 3) on L-6555 Three-phase MVA (1)

Location	Without IR#735	With IR#735
Maximum Generation Conditions - All transmission facilities in service		
POI (138 kV)	1276	1552
Interconnection Facility (138 kV)	757	1080
Interconnection Facility (34.5 kV)	459	908
100N-Higgins (IR#669) (138 kV)	1397	1519
74N-Springhill (138 kV)	1329	1546
Minimum Generation Conditions (TC3, LG1, ML In-Service)		
Interconnection Facility (138 kV), all lines in-service	625	949
Interconnection Facility (138 kV), L-6555 open at 100N (IR#669)	459	783
Interconnection Facility (138 kV), L-6555 open at 74N	372	695
Interconnection Facility (34.5 kV), all lines in-service	407	856
Interconnection Facility (34.5 kV), L-6555 open at 100N (IR#669)	330	778
Interconnection Facility (34.5 kV), L-6555 open at 74N	282	730

(1) Classical fault study, flat voltage profile

The maximum short circuit analysis for the system under normal condition shows that the development of IR#735 will not require upgrades in the local substation breakers.

Inverter-based generation installations often have a minimum Short Circuit Ratio (SCR) for proper operation of converters and control circuits. The minimum short circuit ratio at the 34.5 kV ICIF bus is 2.7 with all lines in service and IR#735 offline. This falls to 2.2 and 1.9 with L-6555 open at 100N-Higgins and L-6555 open at 74N-Springhill, respectively.

Documentation supplied by the IC states that a study is needed to optimize the turbine for connections with SCRs between 1.5-3.0. These expected SCR conditions should be discussed with the wind turbine manufacturer to determine if the equipment can operate, or if modifications are required. The NSPI system short circuit level is expected to decline over time with changes to transmission configuration and generation mix, as noted in TSIR section 7.4.15. Windfarms in proximity to IR#735 (e.g. IR#669) will also reduce the effective SCR in the area. The impact of the low SCR will be further examined when detailed data for the machine is made available for the SIS.

6 Voltage Flicker and Harmonics

The voltage flicker calculations use IEC Standard 61400-21 based on estimated data provided by Nordex Delta4000 N163 6.8 MW wind turbines (4.0 flicker coefficient $c(\psi_k, v_a)$ at 85° system angle). The flicker step factor $K_f(\psi_k)$ for switching operations at a system angle of 85° is given as 0.2 for start-up at both cut-in wind speed and rated wind speed. The maximum number of switching operations within a 10-minute period (N10m) is given as 1. The maximum number of switching operations within a 120-minute period (N120m) is given as 10 for cut-in speed and 12 for rated wind speed. The voltage flicker P_{st} and P_{lt} levels are calculated at the Interconnection Facility for various system conditions and are shown in Table 4 below.

Table 4: Calculated Voltage Flicker at 138 kV Bus

System Conditions	P_{st}=P_{lt} Continuous	Switching			
		P_{st}		P_{lt}	
		Cut-in speed	Rated speed	Cut-in speed	Rated speed
Maximum Generation					
All Transmission in Service	0.120	0.060	0.060	0.054	0.058
Minimum Conditions (TC3, LG1, ML In-Service)					
All Transmission in Service	0.136	0.068	0.068	0.062	0.065
L-6555 open at 100N	0.165	0.082	0.082	0.075	0.079
L-6555 open at 74N	0.185	0.092	0.092	0.084	0.089

NSPI's required limits are 0.35 for P_{st} and 0.25 for P_{lt}. IR#735 is able to meet the flicker requirement in all studied system conditions, including both N-1 minimal generation conditions. This should be further evaluated in the SIS.

The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 2.5%, with no individual harmonic exceeding 1.5% on 138 kV.

7 Load Flow Analysis

The load flow analysis was completed for Spring Minimum Load (SML), Summer Shoulder Load (SSH), Summer Peak Load (SUM) and Winter Peak Load (WIN) cases with varying dispatch scenarios intended to cover a broad range of operating conditions.

Table 5 includes the list of base cases considered, along with a brief description.

Table 5: List of Base Cases	
Case Name	**Description**
SML_01	Spring Minimum Load with low wind (nearby and other WTG at 17%)
SML_02	Spring Minimum Load with high wind (nearby and other WTG at 43% and 17%, respectively)
SSH_01	Summer Shoulder Load with low wind (nearby and other WTG at 17%)
SSH_02	Summer Shoulder Load with high wind (nearby and other WTG at 53% and 17%, respectively)
SUM_01	Summer Peak Load with low wind (nearby and other WTG at 17%)
SUM_02	Summer Peak Load with high wind (nearby and other WTG at 100% and 29%, respectively)
SUM_03	Summer Peak Load with high wind (nearby and other WTG at 100% and 50%, respectively). Power flow between NS and NB stressed to 150 MW import.
SUM_04	Summer Peak Load with high wind (nearby and other WTG at 100% and 50%, respectively). Power flow between NS and NB stressed to 500 MW export.
WIN_01	Winter Peak Load with low wind (nearby and other WTG at 17%)
WIN_02	Winter Peak Load with high wind (nearby and other WTG at 100% and 73%, respectively)
WIN_03	Winter Peak Load with high wind (nearby and other WTG at 100% and 74%, respectively). Power flow between NS and NB stressed to 150 MW import.
WIN_04	Winter Peak Load with high wind (nearby and other WTG at 100% and 35%, respectively). Power flow between NS and NB stressed to 350 MW export.

These 12 base scenarios were studied with and without IR#735. This FEAS added IR#735 and displaced an equivalent amount of existing generation according to dispatch guidelines developed by NSPI[4]. Figure 3 shows the relevant corridors, generators and loads on the NSPI transmission system. The arrow by each corridor shows the power flow direction of positive values.

[4] Thermal generation was decreased to Pmin based on a standard merit order, followed by small hydro units. If further generation was required to be decreased, "other" wind farms (i.e., not "nearby" wind farms that would impact thermal overloads near the IC) were decreased.

Figure 3 Relevant transmission interfaces

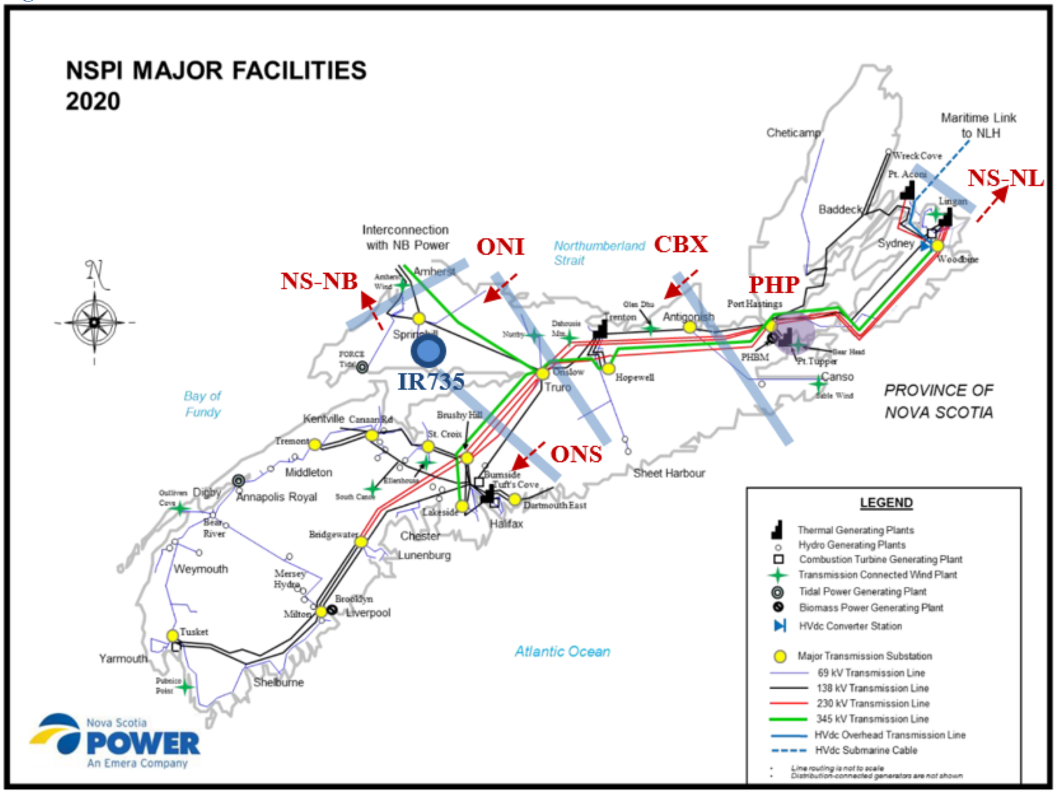


Table 6 summarizes the base cases and the dispatch scenarios to compare the effect of IR#735 on the loading of key NS corridors and generators. The case name followed by 1 (e.g., SML_01-1) stands for the case without IR#735 and the case name followed by 2 (e.g., SML_01-2) stands for the case with IR#735.

Case	NS-Load	NS-NB	NS-NL	ONS	ONI	CBX	PHP	Wind	IR#735
SML_01-1	727	151	-170	-94	68	39	176	236	-
SML_01-2	727	146	-170	26	41	12	176	236	150
SML_02-1	759	148	-170	113	170	-30	209	521	-
SML_02-2	759	149	-170	113	81	-30	209	371	150
SSH_01-1	1161	151	-330	163	369	291	146	236	-
SSH_01-2	1161	145	-330	290	345	289	146	236	150
SSH_02-1	1157	148	-330	423	505	246	146	570	-
SSH_02-2	1157	150	-330	423	417	246	146	420	150
SUM_01-1	1545	150	-330	411	659	558	145	236	-
SUM_01-2	1545	151	-330	411	516	411	145	236	150
SUM_02-1	1604	149	-330	489	592	274	207	905	-
SUM_02-2	1604	149	-330	600	560	268	207	760	150
SUM_03-1	1579	-149	-170	469	273	-56	207	936	-

Case	NS-Load	NS-NB	NS-NL	ONS	ONI	CBX	PHP	Wind	IR#735
SUM_03-2	1579	-149	-170	579	240	-61	207	791	150
SUM_04-1	1521	503	-475	305	765	518	145	936	-
SUM_04-2	1521	498	-475	410	720	471	145	936	150
WIN_01-1	2354	0	-170	855	1040	886	15	236	-
WIN_01-2	2354	3	-170	855	899	790	15	236	150
WIN_02-1	2349	-1	-170	793	832	445	15	1290	-
WIN_02-2	2349	0	-170	904	800	439	15	1140	150
WIN_03-1	2340	-150	-170	890	780	416	15	1153	-
WIN_03-2	2340	-153	-170	1004	747	410	15	1004	150
WIN_04-1	2336	351	-330	736	1130	825	15	800	-
WIN_04-2	2336	352	-330	736	986	673	15	800	150

(1) For inter-area flows, +ve indicates export and -ve indicates import.
(2) The Wind column accounts only for transmission-connected wind facilities (excluding the IR under study).

Due to the newly introduced wind generation by IR#735, the loading of corridors such as Onslow Import (ONI) and Cape Breton Export (CBX) has decreased in most cases due to the displacement of generation in the east of the province. The Onslow South (ONS) corridor is generally unaffected in the cases studied, as the Tuft's Cove generation was not displaced based on the merit order. Varied inter-province power flows between NS-NB are represented in the base cases to test the effect of IR#735 integration.

Single contingencies were applied at the 345 kV, 230 kV, 138 kV, and 69 kV voltage levels for the above system conditions with and without IR#735. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limit for each contingency. Contingencies studied are listed in Table 7.

Table 7: Contingencies Studied				
88S_L7014	3C_711	1N_C61	91H_L5041	99W_T72
88S_L7021	3C_712*	1N_B61	91H_T62	DCT_L5039_L6033
88S_L7022	3C_713	1N_B62	91H_T11	DCT_L7009_L8002
88S_710	3C_714	1N_600	91H_511	DCT_L6011_L6010
88S_711	3C_715*	1N_601	91H_516	DCT_L6010_L6005
88S_713	3C_716	1N_613	91H_521	DCT_L6005_L6016
88S_714	2C_L6515	120H_L7008	91H_523	DCT_L7008_L7009
88S_715	2C_L6516	120H_L7009	91H_G3	DCT_L7003_L7004*
88S_720	2C_L6517	120H_L6005	91H_G4	DCT_L7024_L7004*
88S_721	2C_L6518	120H_L6010	91H_G5	DCT_L6507_L6508
88S_722	2C_L6537	120H_L6011	91H_G6	DCT_L7021_L6534
88S_723*	2C_B61	120H_L6051	14H_GT1	DCT_L6033_L6035
88S_T71	2C_B62	120H_L6016	14H_GT3	85S_L6545
88S_T72	79N_L8003*	120H_T71	83S_GT1	5S_L6538

Table 7: Contingencies Studied				
88S_G2	79N_L6507	120H_T72	83S_GT2	3S_L6539
88S_G3	79N_L6508	120H_SVC	85S_GT1	5S_L6537
88S_G4	79N_T81*	120H_710	85S_GT2	5S_L6516
101S_ML_POLE1	67N_L8001*	120H_711	132H_602	5S_606
101S_ML_POLE2	67N_L8002	120H_712	132H_603	5S_607
101S_ML_BIPOLE	67N_L7019	120H_713	132H_605	2S_513
101S_T81	67N_L7001	120H_714	132H_606	89S_G1
101S_T82	67N_L7002	120H_715	91N_701	1C_G2
101S_L7011*	67N_L7018	120H_716	91N_702	48C_G1
101S_L7012*	67N_T81	120H_720	91N_703	50N_G5
101S_L7015	67N_T82	120H_621	91N_B71	50N_G6
101S_L8004*	67N_T71	120H_622	125C_L7025	104W_G1
101S_701	67N_811*	120H_623	125C_701	110W_T62
101S_702	67N_812	120H_624	125C_B71	104H_600
101S_703	67N_813	120H_626	127C_L7003	30N_B61
101S_704	67N_814*	120H_627	127C_701	30N_T61
101S_705	67N_701	120H_628	127C_B71	74N_B61
101S_706	67N_702	120H_629	102N_L7005	74N_C61
101S_711	67N_703	103H_L6008	102N_701	74N_IR735
101S_712	67N_704	103H_L6033	102N_B71	74N_L6514
101S_713	67N_705	103H_L6038	100N_L6555	74N_L6536
101S_811	67N_706	103H_T81	100N_601	74N_L6555
101S_812*	67N_710	103H_T61	100N_B61	74N_T61
101S_813*	67N_711*	103H_T63	101V_L6054	SALISBURY_L3004
101S_814	67N_712	103H_B61	101V_L6004	SALISBURY_L3013
101S_816	67N_713	103H_B62	101V_601	SALISBURY_SA3_2*
3C_L7024	1N_L6613	103H_881	99W_BESS	SALISBURY_L3006*
3C_L7004	1N_L6503	103H_600	43V_BESS	MEMRAMCOOK_L1159
3C_L7027*	1N_L6001	103H_608	132H_BESS	MEMRAMCOOK_L1160
3C_T71	1N_T1	103H_681	99W_708	MEMRAMCOOK_ME3_1*
3C_T72	1N_T4	91H_L5049	99W_709	
3C_710*	1N_T65	91H_L5012	99W_T71	

Note: Contingencies marked with * denotes applicable in service RAS may be armed.

7.1 Load Flow Results

With the interconnection of IR#735 as NRIS, some contingencies resulted in thermal overload on L-6001. Table 8 shows the highest thermal overloads found. No contingencies resulted in a violation of voltage limit criteria.

Table 8: Contingencies Resulting in Highest Line Overload			
Line	Overload (% of Emergency Rating)	Case	Contingency
L-6001	101.3	WIN_03	c_67N_812, c_67N_813

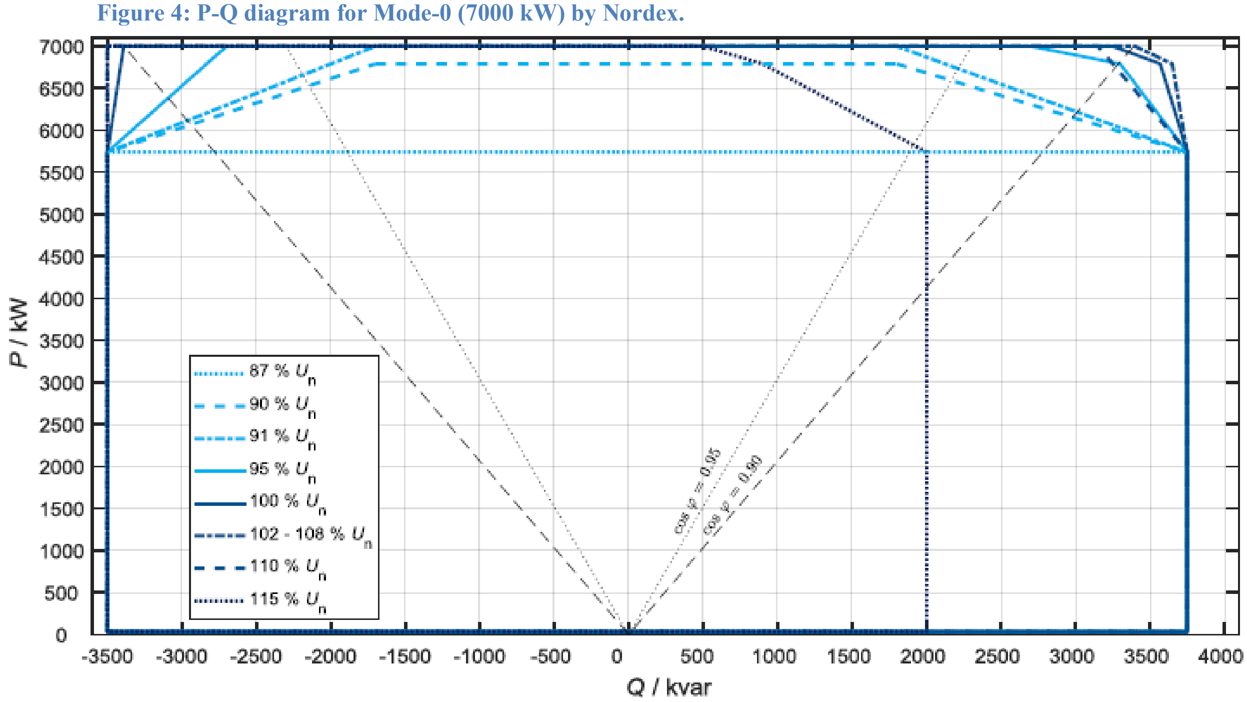
The case WIN_03 represents high flows on the Onslow South (ONS) corridor which are increased above the allowed range following the addition of IR#735. Following re-dispatch of the corridor below existing limits, the L-6001 thermal overload is resolved and is therefore not the responsibility of IR#735. This thermal overload will be investigated further in the SIS stage.

The arming values for the existing RAS 'NS Import Power Monitor' and 'NS Export Power Monitor' will be further evaluated in the SIS. Since the lines L-6613/L-6555 are elements of both the 'NS Import Power Monitor' and 'NS Export Power Monitor' RASs, they will require changes to accommodate IR#735. Modifications are subject to approval by the NPCC.

8 Reactive Power and Voltage Control

In accordance with TSIR Section 7.6.2, IR#735 must be capable of delivering reactive power for a net power factor of at least +/- 0.95 of rated capacity to the high side of the plant interconnection transformer(s). A STATCOM, rated at +/- 36 MVAr, has been added by the Interconnection Customer to provide reactive power support. The P-Q diagram for Mode-0 (7000 kW) by Nordex is shown in Figure 4.

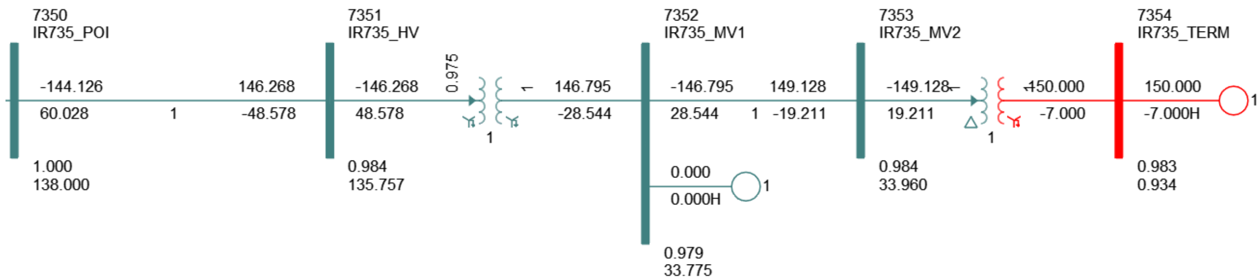
Figure 4: P-Q diagram for Mode-0 (7000 kW) by Nordex.



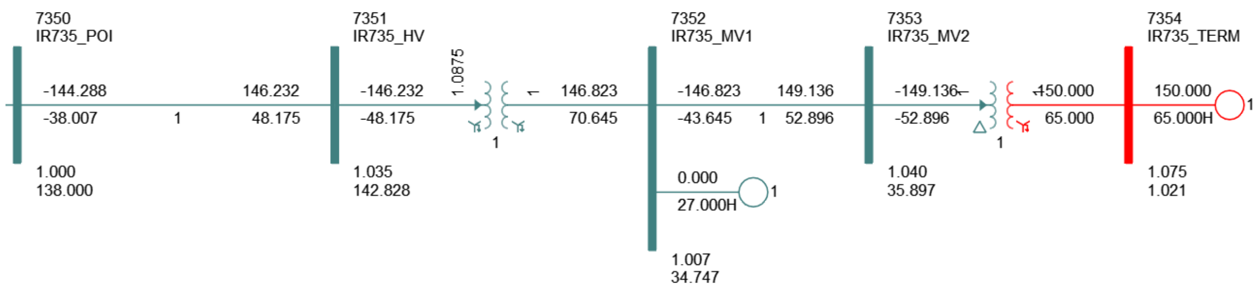
When the active power is zero, the reactive power capability of the wind turbine is zero. The optional "STATCOM function" can be added to inject/absorb reactive power when active power is zero, at a reduced capacity.

The power factor analysis is conducted using a SMIB (Single Machine Infinite Bus) case for IR#735. The leading and lagging power factor analysis for IR#735 results in power factor values less than 0.95. This verifies the ability of the configuration to meet the power factor requirement. Analysis shown in Figure 5 verifies the reactive power capability of the system.

Figure 5: Power Factor Analysis



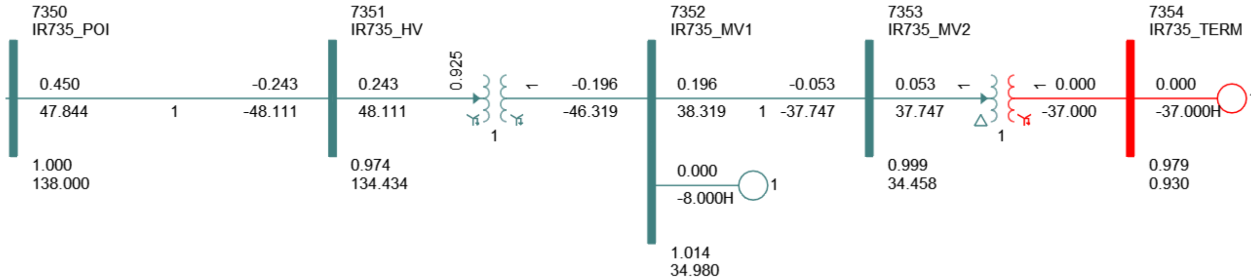
SMIB case: Leading Power Factor



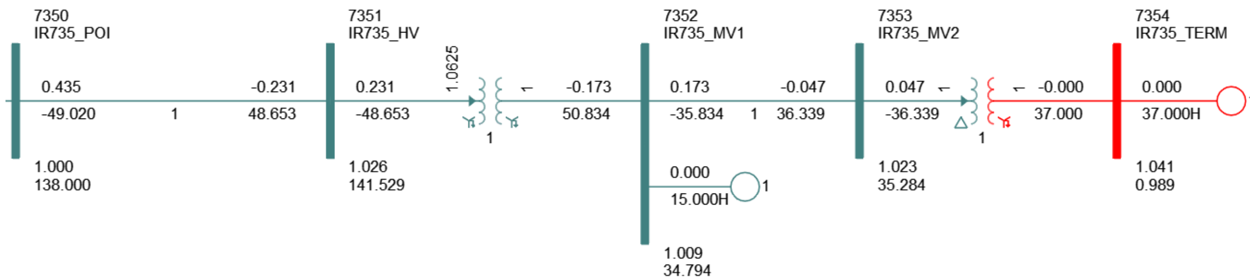
SMIB case: Lagging Power Factor

A sensitivity test was performed with the wind turbine operating in STATCOM mode. In STATCOM mode, the reactive power limits of the wind turbine are reduced. The IC is able to match the rated reactive power at maximum active power output for leading and lagging power factor.

Figure 6: Power Factor Analysis: STATCOM Mode



SMIB case: Leading Power Factor



SMIB case: Lagging Power Factor

A centralized controller will be required which continuously adjusts individual generator reactive power output within the plant capability limits and regulates the voltage at the 34.5 kV bus voltage. The voltage controls must be responsive to voltage deviations at the terminals of the interconnection facility substation, be equipped with a voltage set-point control, and can slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generator capabilities. The details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation. Line drop compensation, voltage droop, control of separate switched capacitor banks must be provided.

The NSPI System Operator must have manual and remote control of the voltage set-point and the reactive set-point of this facility to coordinate reactive power dispatch requirements.

This facility must also have low voltage ride-through capability as per Appendix G of the Standard Generator Interconnection and Operating Agreement (GIA). The SIS will state specific options, controls and additional facilities that are required to achieve this.

An on-load tap changer will be required on the ICIF transformer. Settings for the ICIF on-load tap-changer must be coordinated with plant voltage controller for long-term reactive power and voltage management at the POI.

9 Bulk Electric / Bulk Power Analysis

The 1N-Onslow substation and line L-6613 are currently classified as part of the NERC Bulk Electric System (BES) and are subject to the applicable NERC Reliability Criteria. The IR#735 138 kV POI bus will also be classified as a BES element. As IR#735 has dispersed generation totaling more than 75 MVA, Inclusion I4 of the NERC BES Definition applies; each generator and systems designed for delivering that aggregate capacity to the POI classified are categorized as BES elements.

The 138 kV bus at the 1N-Onslow substation and the line L-6613 are part of the NPCC Bulk Power System (BPS). L-6555 is expected to be classified as a BPS element. As such, all protection systems associated with the expansion of the IR#735 ring bus POI substation must comply with NPCC Directory 4 *System Protection Criteria*.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#735 to the NSPI transmission system at a POI on L-6555 under NRIS or ERIS:

a. Required Network Upgrades

- Install a new 138 kV substation complete with 3 breaker ring bus at the POI on L-6555 with control and protection. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA system, with telemetry and controls as required by NSPI.
- Changes to existing NSPI Limited Impact RAS (NS Import Monitor and NS Export Monitor) arming/limit values.

b. Required Transmission Provider's Interconnection Facilities (TPIF):

- Construct a 30 km, 138 kV transmission line between the POI and the ICIF substation. This line would be built to NSPI's 138 kV standards.
- Supervisory, control, and communications between the wind farm and NSPI SCADA system (to be specified).

c. Required Interconnection Customer's Interconnection Facilities (ICIF)

- Facilities to provide 0.95 leading and lagging power factor when delivering rated output at the HV terminals of the IC Substation Step Up Transformer when the voltage at that point is operating between 95 and 105% of nominal.

- Centralized controls. These will provide centralized voltage set-point controls and are known as Farm Control Units (FCU). The FCU will control the 34.5 kV bus voltage and the reactive output of the machines. Responsive (fast-acting) controls are required. The controls will also include a curtailment scheme which will limit or reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system.
- NSPI will have control and monitoring of reactive output of this facility, via the centralized controller. This will permit the NSPI Operator to raise or lower the voltage set-point remotely.
- Low voltage ride-through capability per Section 7.4.1 of the TSIR.
- Real-time monitoring (including an RTU) of the interconnection facilities. Local wind speed and direction, MW and MVAr, as well as bus voltages are required.
- Facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined in SIS. The plant may be incorporated into RAS run-back schemes.
- Automatic Generation Control to assist with tie-line regulation.
- Compliance with section 7.6.7 of TSIR, "WECS Generating Facilities shall support short-duration frequency deviations by providing inertia response equivalent to a Synchronous Generator with an inertia factor (H) of at least 3.0 MW-s/MVA for a period of at least 10 seconds." This item will be assessed in the SIS, which may identify additional resources such as synchronous condenser, Flexible AC Transmission System (FACTS) devices, etc.
- Operation at an ambient temperature of -30°C, section 7.6.9 of the TSIR.
- The facility must meet NSPI's TSIR as published on the NSPI OASIS site.
- NS Power notes that NERC standard PRC-029-1 is currently in development. As proposed, this standard will impose performance requirements for voltage and frequency ride through behaviour on inverter-based generating resources. It is anticipated that this standard will be applicable to the project currently under study. The Interconnection Customer is advised to consider the requirements of PRC-029-1 in their project design to ensure that their project can conform to these requirements. Conformance will be validated at the System Impact Study stage.

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 150 MW wind energy at the 138 kV POI on L-6555 as NRIS or ERIS are included in Table 9.

Table 9 Cost Estimate @ POI L-6555		
Item	**Network Upgrades**	**Estimate**
1	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L-6555, including P&C modifications at 74N-Springhill and 100N-Higgins. The IC is also responsible for providing the substation site and access road.	$7,000,000
2	Modifications to Limited Impact RAS (NS Import Monitor and NS Export Monitor) arming/limit settings	$400,000
	Sub-total for Network Upgrades	$7,400,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 30 km 138 kV spur line from TPIF to ICIF, with IC responsible to provide right-of-way	$27,300,000
2	NSPI P&C relaying equipment	$300,000
3	NSPI supplied RTU	$100,000
4	Tele-protection and SCADA communications	$750,000
	Sub-total for TPIF Upgrades	$28,450,000
	Total Upgrades	**Estimate**
	Network Upgrades + TPIF Upgrades	$35,850,000
	Contingency (25%)	$8,962,500
	Total (Incl. 25% contingency and Excl. HST)	$44,812,500

The preliminary non-binding cost estimate for interconnecting IR#735 at the POI at L-6555 under NRIS is $44,812,500 including a contingency of 25%. In this estimate, $7,400,000 (plus 25% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP. This does not include costs to address any potential stability issues identified at the SIS stage based on dynamic analysis, costs related to findings of the electromagnetic transient (EMT) analysis, and it assumes that RAS modification is approved by NPCC.

The estimated time to construct the Transmission Providers Interconnection Facilities and the Network Upgrades is 24-36 months is 18-24 months after receipt of funds and cleared right of way from the IC.

12 Loss Factor

Loss factor is calculated by running the winter peak load flow case (WIN_01) with and without the new facility in service, while keeping 91H-Tufts Cove as the NS Area interchange bus. This methodology reflects the load center in and around 91H-Tufts Cove. A negative loss factor reflects a reduction in system losses.

The loss factor is calculated using the equation (01) and the data given in Table 11.

$$Loss\ Factor = \frac{(IR735_{POI} + TC_{withIR735}) - TC_{withoutIR735}}{IR735_{POI}} \quad (01)$$

Table 11: Data for Loss Factor Calculation

Parameter/Measurement	Value (MW)
Power at POI of IR#735	144.9
Power generation at TC with IR#735	9.8
Power generation at TC without IR#735	148.4
Loss Factor	**4.3 %**

13 Preliminary Scope of Subsequent SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#735.

The SIS will include a more comprehensive assessment of the technical issues and requirements to interconnect generation as requested. It will include contingency analysis, system stability, transient stability, ride through capability, and operation following a contingency (N-1 operation). The SIS must determine the facilities required to operate this facility at full capacity, withstand any contingencies (as defined by the criteria appropriate to the location) and identify any restrictions that must be placed on the system following a first contingency loss.

The SIS will confirm the options and ancillary equipment that the customer must install to control flicker, voltage response, frequency response, control interactions with other IBR facilities, active power and ensure that the facility has the required ride-through capability. The SIS will be conducted in accordance with the GIP with the assumption that all appropriate higher-queued projects proceed, and the facilities associated with those projects are installed. The following notice on OASIS provides additional clarification on the SIS model requirements:

NSPI-TPR-015-2: PSSE and PSCAD Model Requirements and NSPI-TPR-014-1: Model Quality Testing will undergo revision as the grid evolves and performance criteria changes. The most up to date version will be provided as they become available.

To be eligible for inclusion in the Interconnection System Impact Study stage, and thereby advance the Interconnection Request's initial Queue Position, the Interconnection Customer must meet the progression milestone requirements of Section 7.2 of the GIP at least ten (10) Business Days prior to the Interconnection System Impact Study commencement date. For clarity, item 7.2 (i) – provision of a detailed stability model for the generator(s) shall mean:

- ***Provision of PSSE and PSCAD models in compliance with documents NSPI-TPR-015-2: PSSE and PSCAD Model Requirements, and***
- ***Provision of test data demonstrating model testing in compliance with NERC, NPCC and NSPI criteria. NSPI-TPR-014-1: Model Quality Testing lists the minimum requirements that will be performed by NSPI. Additional testing may be performed to assess compliance with all applicable criteria. Any test not meeting the minimum NSPI requirements will be documented in the MQT report to the IC.***

The following outline provides the minimum scope that must be complete to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives.

The assessment will consider but not be limited to the following:

- Facilities that the customer must install to meet the requirements of the GIP and the TSIR.
- The minimum transmission additions/upgrades that are necessary to permit operation of this Generating Facility, under all dispatch conditions, catering to the first contingencies listed.
- Guidelines and restrictions applicable to first contingency operation (curtailments etc.).
- Under-frequency load shedding impacts.

The SIS will assess system contingencies such that the system performance will meet the following criteria:

- Table 1 "Planning Design Criteria" of NPCC Directory 1.
- Table 1 "Steady State & Stability Performance Planning Events" of NERC TPL-001-5.1.
- NSPI System Design Criteria, report number NSPI-TPR-003-6.

Any changes to RAS schemes required for operation of this generating facility, in addition to existing generation and facilities that can proceed before this project, will be determined by the SIS as well as any required additional transmission facilities. The determination will be based on NPCC[5] and NERC[6] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

[5] NPCC criteria are set forth in its Reliability Reference Directory #1 Design and Operation of the Bulk Power System

[6] NERC transmission criteria are set forth in NERC Reliability Standard TPL-001-5.1